Burning Materials

Table 8 shows the number of fires by burning material and time period. The materials most often involved were electrical cables, starters, voltage boxes, rectifiers, electrical insulation, breakers, transformers, and batteries. These were followed by coal and coal dust; belts, feeders, drives, and pulleys; and oxyfuel, grease, and clothing. Other burning materials were flammable liquids, methane, elevator shafts and motors, oil and resin, hydraulic fluids, and gearboxes.

During the first period, the largest number of fires involved oxyfuel, grease, and clothing materials. During the second, third, and fifth periods, the largest number of fires involved electrical cables, wires, starters, voltage boxes, transformers, starters, and batteries. During the fourth period, the largest number of fires involved coal and coal dust (see table 8). By comparison, data from Pomroy and Carigiet [1995] for 1978–1992 show that the most frequent burning materials in underground coal mines were coal and coal dust, electrical insulation, oil and grease, conveyor belts and rollers, wood, rubber hoses, and tires.

Fire Injuries

Table 9 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location during 1990–1999. Overall, there were 34 injuries caused by 27 fires. The greatest number of fire injuries occurred in 1990 (10 injuries caused by 4 fires) and 1991 (7 injuries caused by 7 fires). The ignition sources that caused most of the fire injuries were electrical short/arcing, battery explosion, and flame cutting/welding spark/slag/flames. Other ignition sources were conveyor belt friction, heat source, and refueling fuel on hot surfaces. The equipment most often involved in fire injuries were electrical power cables, voltage boxes, oxyfuel torches, beltlines, drives, pulleys and feeders, and mobile equipment. The most common locations for fire injuries were pump, power and charging stations, mobile equipment working areas, flame cutting/welding areas, trolley track rails and transportation areas, and belt entries.

By comparison, data from Pomroy and Carigiet [1995] for 1978–1992 show that the ignition sources causing the most of the fire injuries were electrical short/arcing, belt friction, and flame cutting/welding sources. The equipment most often involved in fire injuries and fire fatalities included air compressors (which caused 27 fatalities during one fire), trolley power cables, and oxyfuel torches. The most common locations for fire injuries were main intakes, belt entries, longwall headgate, working faces, and track entries.

SURFACE OF UNDERGROUND COAL MINE FIRES

Table 10 and figure 4 show the number of fires and fire injuries occurring at the surface of underground coal mines by state during 1990–1999. Table 10 also shows by state the risk rate, employees' working hours, and lost workdays.

A total of 65 fires occurred in 10 states. Thirteen of those fires caused 12 injuries and 1 fatality (the yearly average was 6.5 fires and 1.2 injuries). Four fires and one fire injury involved contractors. The Ewhr value was 97×10^6 hr (Irr = 0.025); the LWD value was 6,206. Pennsylvania had the most fires (20 fires and 5 injuries), followed by West Virginia (16 fires and 1 fatality) and Kentucky (15 fires and 3 injuries). Among these states, Pennsylvania had the highest injury risk rate value (Irr = 0.095).

Table 11, partly illustrated in figure 5, shows by time period the number of fires, fire injuries, and fire fatalities; risk rates; employees' working hours; and lost workdays. The number of fires and fire injuries show a decrease followed by an increase during the five time periods, accompanied by a decline in employees' working hours throughout the periods (see table 11 and figure 5). The Irr values follow patterns similar to those shown by the injury values.

Tables 12–17 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 6 shows the major variables during 1990–1999. Table 18 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Ignition Source

The number of fires and fire injuries by ignition source and time period is shown in tables 12 and 18. The leading sources were hydraulic fluid/fuel sprayed onto equipment hot surfaces (11 fires or 17% with 1 injury), spontaneous combustion/hot coal (11 fires or 17%), and flame cutting/welding spark/slag/flames (11 fires or 17% with 7 injuries). Three of the mobile equipment hydraulic fluid/fuel fires became large fires, which at times required fire department interventions. In at least two instances flames erupted in the cab, probably because of the ignition of flammable vapors and mists that penetrated the cab. Of note is that most of the hydraulic fluid/fuel fires were caused when hydraulic fluids sprayed onto equipment hot surfaces; subsequently, these fires involved the fuel lines. The flame cutting/welding spark/slag/flame source caused fires usually involving welders' clothing or oxyfuel/grease (grease embedded in the equipment's mechanical components). However, in one instance sparks/hot slag/flames caused a methane ignition followed by a large fire, and twice undetected hot slag caused coal belt fires. Other ignition sources were heat source (four fires), electrical short/arcing (four fires), conveyor belt friction (three fires), and overheated oil (one fire). Twenty ignition sources (mostly affecting facilities) were unknown.

During the first period, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces. During the second period, the largest number of fires were caused by spontaneous combustion/hot coal. During the third and fourth periods, the largest number of fires were caused by the flame cutting/welding spark/slag/flame source. During the fifth period, the largest number of fires were caused by flame cutting/welding spark/slag/flames, spontaneous combustion/hot coal, and hydraulic fluid/fuel sprayed onto equipment hot surfaces (see table 12).

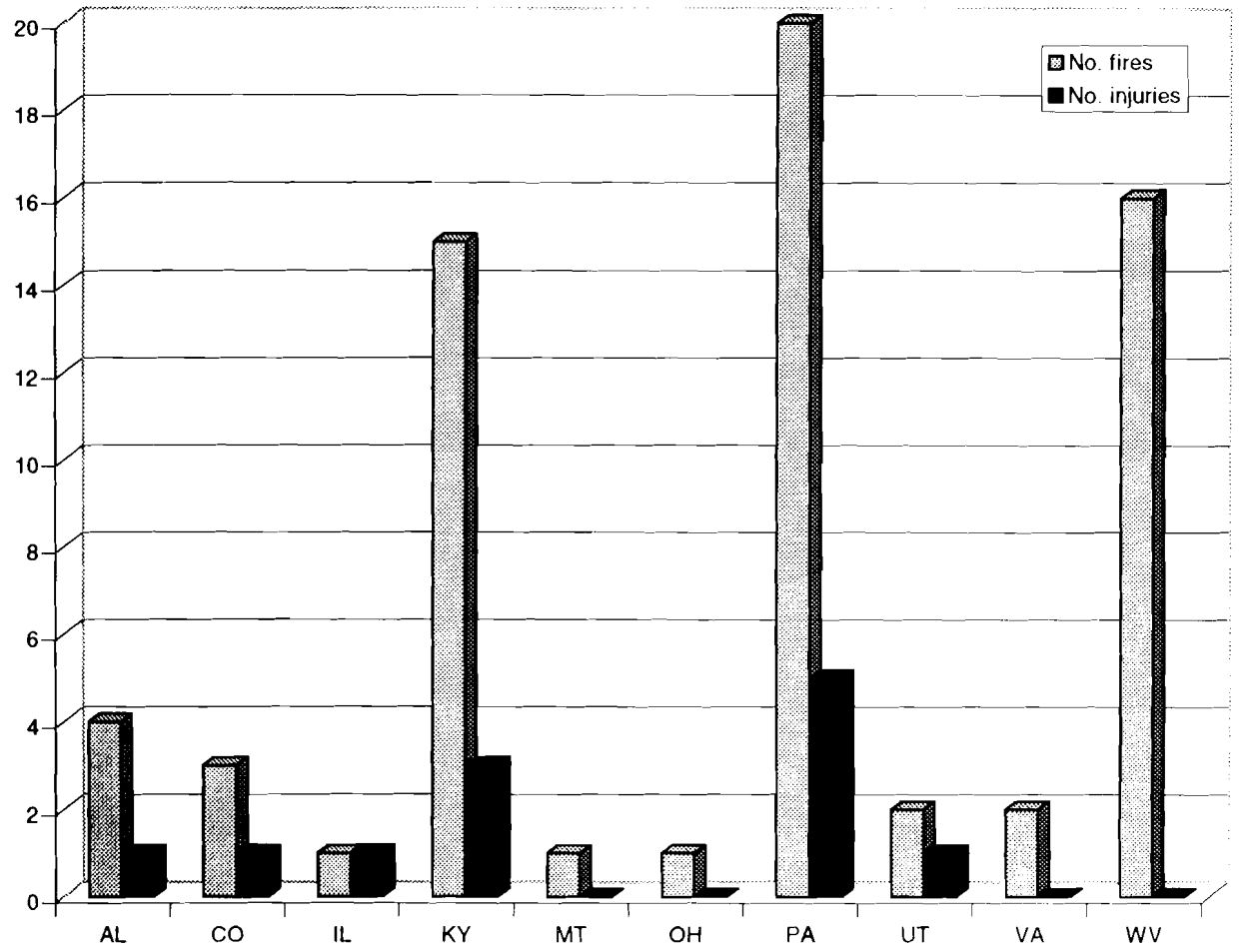

Figure 4.—Number of fires and fire injuries for surface of underground coal mines by state, 1990–1999.

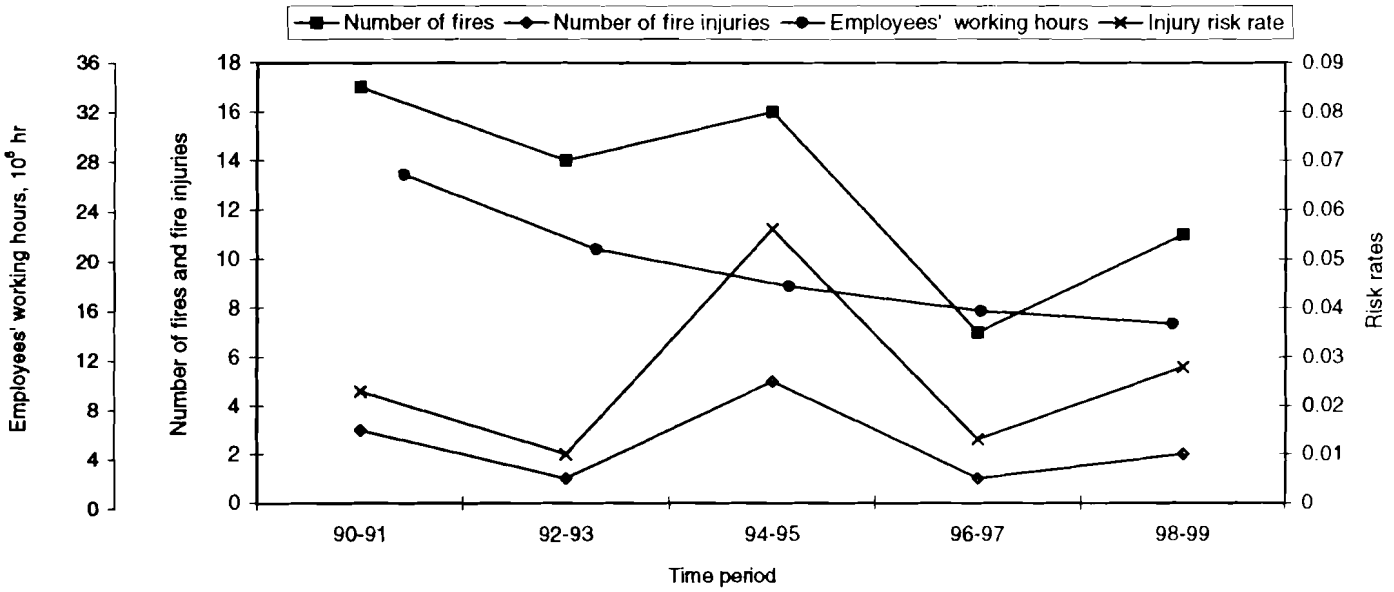

Figure 5.—Number of fires, fire injuries, and risk rates for surface of underground coal mines by time period and employee' working hours, 1990–1999.

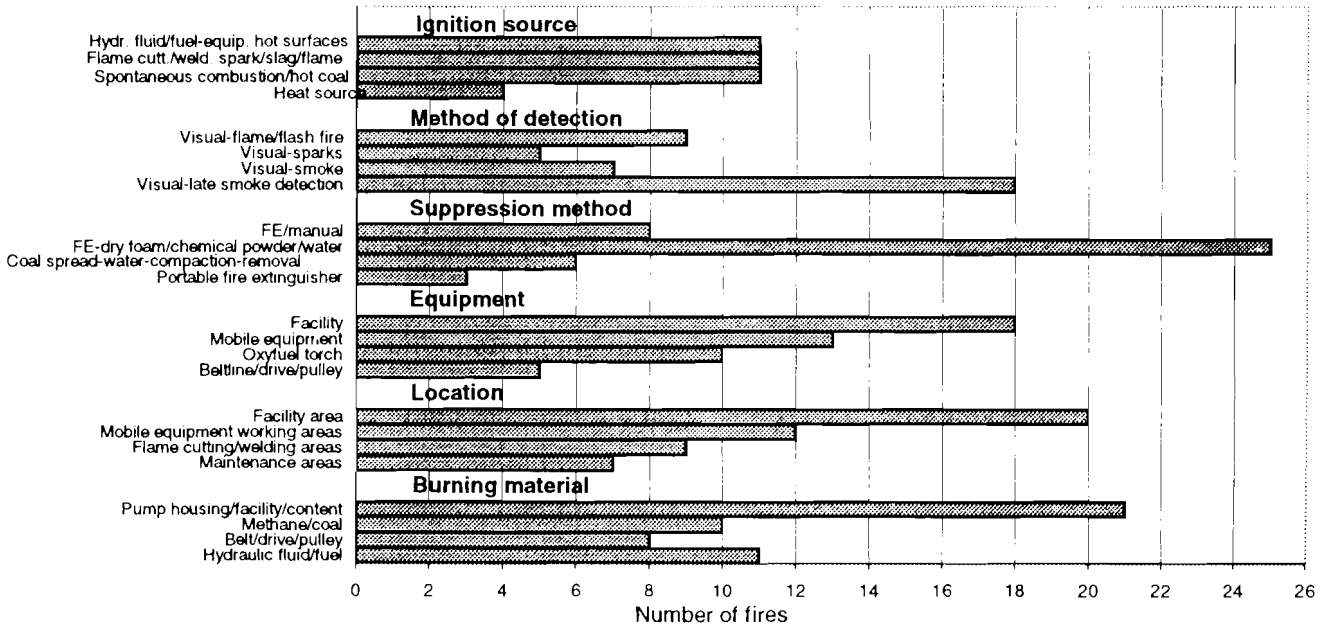

Figure 6.—Major variables for surface of underground coal mine fires, 1990–1999. (FE = portable fire extinguisher)

Table 10.—Number of fires, fire injuries, and risk rates for surface of underground coal mines by state, employees' working hours, and lost workdays, 1990–1999

State[1]	No. fires[1]	No. injuries[1]	LWD[2]	Ewhr,[2] 10^6 hr	Irr[3]
Alabama	4	1	4	5.8	0.035
Colorado	3	1	—	3.6	0.056
Illinois	1	1	42	6	0.033
Kentucky	15	3	88	23	0.026
Montana	1	—	—	0.12	—
Ohio	1	—	—	3.7	—
Pennsylvania	20	5	24	10.5	0.095
Utah	2	1	6	4	0.05
Virginia	2	—	42	11	—
West Virginia[4]	16	—	6000	20.4	—
Other states	—	—	—	8.8	
Total	65	12	6206	97	30 025

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Coal Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.
[4]West Virginia had 1 fire fatality.

Table 11.—Number of fires, fire injuries, fire fatalities, and risk rates for surface of underground coal mines by time period, employees' working hours, and lost workdays, 1990–1999

	Time period					
	90-91	92-93	94-95	96-97	98-99	90-99
Number of fires[1]	17	14	16	7	11	65
Number of fire injuries[1]	3	1	5	1	2	12
Number of fire fatalities	1	—	—	—	—	1
LWD[2]	6000	24	88	10	84	6206
Ewhr,[2] 10^6 hr	27	21	18	16	15	97
Irr[3]	0.023	0.01	0.056	0.0125	0.028	30 025

[1]Derived from MSHA "Fire Accident Abstract" and "Fire Accident Report" publications.
[2]Derived from MSHA "Injury Experience in Coal Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 12.—Number of fires for surface of underground coal mines by ignition source and time period, 1990–1999

Ignition source	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Heat source	1	1	2	—	—	4
Flame cutting/welding spark/slag/flame[1]	2	1	4	2	2	11
Electrical short/arcing	3	—	—	—	1	4
Spontaneous combustion/hot coal	2	3	3	1	2	11
Conveyor belt friction	1	1	—	1	—	3
Hydraulic fluid/fuel on equipment hot surfaces	4	2	3	—	2	11
Overheated oil	1	—	—	—	—	1
Unknown/other	3	6	4	3	4	20
Total	17	14	16	7	11	65

[1]This source caused fires usually involving welders' clothing or oxyfuel/grease. However, in one instance undetected hot slag caused a methane ignition followed by a large fire, and twice undetected hot slag caused coal belt fires.

Table 13.—Number of fires for surface of underground coal mines by method of detection and time period, 1990–1999

Method of detection	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Visual method:						
Flames/flash fires	2	2	3	—	2	9
Sparks	2	—	—	1	2	5
Late smoke detection	6	3	4	2	3	18
Smoke	2	1	3	1	—	7
Smoldering	1	1	—	—	—	2
Smelled smoke	—	1	—	—	—	1
Explosion	1	—	2	—	—	3
Undetected	3	6	4	3	4	20
Total	17	14	16	7	11	65

Table 14.—Number of fires for surface of underground coal mines by suppression method and time period, 1990–1999

Suppression method	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Manual/FE[1]	3	—	3	—	2	8
FE-foam/dry chemical powder/water	6	6	7	3	3	25
Coal spread-water-compaction-removal[2]	2	—	1	1	2	6
Destroyed/heavily damaged[3]	3	6	4	3	4	20
Portable fire extinguisher	3	—	—	—	—	3
FE-FSS-dry chemical powder	—	1	1	—	—	2
Other	—	1	—	—	—	1
Total	17	14	16	7	11	65

FE Portable fire extinguisher.
FSS Machine fire suppression system.
[1]Methods used by welders to extinguish clothing or oxyfuel/grease fires.
[2]Methods used to extinguish spontaneous combustion/hot coal fires.
[3]Due to failure of other firefighting methods, late fire detection, or undetected fires.

Table 15.—Number of fires for surface of underground coal mines by equipment involved and time period, 1990–1999

Equipment	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Oxyfuel torch	2	1	3	2	2	10
Beltline/drive/pulley	2	1	1	1	—	5
Heater/maintenance equipment	2	1	2	—	—	5
Electrical power unit/system	1	—	—	—	1	2
Pump	1	—	—	—	—	1
Facilities	2	5	4	3	4	18
Mobile equipment[1]	6	2	3	—	2	13
Other[2]	1	4	3	1	2	11
Total	17	14	16	7	11	65

[1]Includes hoists, loaders, dozers, scrapers, trucks, highlifts, excavators, and tractors.
[2]Includes nonequipment (mostly coal piles).

Table 16.—Number of fires for surface of underground coal mines by location and time period, 1990–1999

Location	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Flame cutting/welding areas[1]	2	—	4	1	2	9
Coal silo/stock/refuse pile	1	2	1	—	2	6
Beltline/drawoff tunnel areas	1	2	2	1	—	6
Power station	2	—	—	—	1	3
Maintenance areas	3	1	3	—	—	7
Facility areas	2	6	4	4	4	20
Mobile equipment working areas[2]	5	3	2	—	2	12
Charging station	1	—	—	1	—	2
Total	17	14	16	7	11	65

[1]Includes beltline areas, storage silos, and mobile equipment maintenance areas.
[2]Includes loading, hoisting, and haulage areas.

Table 17.—Number of fires for surface of underground coal mines by burning material and time period, 1990–1999

Burning material	Time period					
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	90-99 No. fires
Flammable liquids	1	1	2	—	2	6
Electrical wires/systems/batteries	2	—	—	—	1	3
Facility/content/pump housing	4	6	4	3	4	21
Belt/drive/pulley	3	2	2	1	—	8
Coal/methane	1	3	3	1	2	10
Wood ties/refuse pile/electrical insulation	1	—	1	1	—	3
Oxyfuel/grease/clothing	1	—	1	1	—	3
Hydraulic fluid/fuel	4	2	3	—	2	11
Total	17	14	16	7	11	65

Table 18.—Number of fire injuries per number of fires causing injuries and total fires at surface of underground coal mines by year, ignition source, equipment involved, and location, 1990–1999

Year	No. fires causing injuries	No. total fires	No. fire injuries	Ignition source	Equipment	Location
1990	1	7	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
	1	—	1	Battery explosion	Mobile equipment[2]	Charging station.
1991[3]	2	10	1	Hydraulic fluid/fuel on equipment hot surfaces	Mobile equipment[2]	Loadout area.
1992	—	6	—	—	—	—
1993	1	8	1	Training fire	Turnout gear	Fire training area.
1994	2	6	2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1995	2	10	2	Heat source	Heater	Refuse/maintenance areas.
	1	—	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1996	—	2	—	—	—	—
1997	1	5	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch/mobile equipment.[2]	Maintenance areas.
1998	2	5	2	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.[1]
1999	—	6	—	—	—	—
Total	13	65	12			

[1]Includes beltline, drive, and pulley areas; storage silos; shops; and mobile equipment maintenance areas.
[2]Includes highlifts, loaders, and trucks.
[3]During 1991, there was 1 fire fatality.

Method of Detection

Table 13 shows the number of fires by method of detection and time period. The most frequent method of detection was miners who saw smoke long after the fires had started, followed by operators who saw the fires when they had started as flames/flash fires. Other methods of detection were miners who saw smoke shortly after the fires had started; welders who saw sparks; and miners who heard an explosion, saw smoldering of coal, or smelled smoke. Twenty fires were undetected. The largest number of fires were detected late by smoke throughout the periods (table 13).

Suppression Method

Table 14 shows the number of fires by suppression method and time period. The most common methods were dry chemical powder and water, followed by manual techniques with or without portable fire extinguishers (welders' methods to extinguish clothing or oxyfuel/grease fires) and coal spread,

water, compaction, and removal (method used to extinguish spontaneous combustion/hot coal fires). Other fire suppression methods were portable fire extinguishers alone and foam and water.

Two pieces of mobile equipment involved in fires had machine fire suppression systems. Dual activation (one activation) of machine fire suppression and engine shutoff systems failed to temporarily abate the flames because of the flow of pressurized fluids entrapped in the lines (not affected by the engine shutoff operation). Most of the hydraulic fluid/fuel fires became large fires. In at least three instances these fires required fire department interventions because of the continuous flow of fluid/fuel from the pumps due to engine shutoff failure, lack of an emergency hydraulic line drainage system, difficulty in activating available emergency systems at ground level, or lack of effective and rapid local firefighting response capabilities. (Fire-resistant hydraulic fluid is not required for equipment use at surface coal operations.)

Fire brigades and fire departments (required in six instances) fought three mobile equipment fires and other large fires with foam, dry chemical powder, and water. However, 20 fires destroyed or heavily damaged equipment (including two pieces of mobile equipment) because of failure of other firefighting methods, late fire detection, undetected fires, or fire size.

The largest number of fires were suppressed with portable fire extinguishers, foam, dry chemical powder, and water throughout the periods (table 14).

Equipment Involved

Table 15 shows the number of fires by equipment involved and time period. The equipment most often involved included mobile equipment (hoists, dozers, loaders, scrapers, trucks, highlifts, excavators, and tractors) and oxyfuel torches. Other equipment included heaters and maintenance equipment, beltlines, drives and pulleys, maintenance equipment, electrical systems, power units, and pumps.

During the first period, the largest number of fires involved mobile equipment. During subsequent periods, the largest number of fires involved facilities (see table 15).

Location

Table 16 shows the number of fires by location and time period. The most common locations were facilities and mobile equipment working areas (e.g., loading, hoisting, and haulage areas). These were followed by flame cutting/welding areas (at beltline areas, storage silos, and mobile equipment maintenance areas) and maintenance areas. Other fire locations were coal silos, stock and refuse pile areas, beltline and drawoff tunnel areas, and power and charging stations.

During the first period, the largest number of fires occurred at mobile equipment working areas. During subsequent periods, the largest number of fires occurred at facility areas (see table 16).

Burning Materials

Table 17 shows the number of fires by burning material and time period. The materials most often involved were pump housing and facilities/content, followed by hydraulic fluid/fuel, coal and methane, and belts, drives, and pulleys. Other burning materials were flammable liquids, electrical systems, wires and batteries, wood ties, refuse piles, electrical insulation, and oxyfuel/grease/clothing. During the first period, the largest number of fires involved hydraulic fluid/fuel and facility/content materials. During subsequent periods, the largest number of fires involved facility/content materials (see table 17).

Fire Injuries

Table 18 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location during 1990–1999. Overall, 13 fires caused 12 injuries and 1 fatality.

The greatest number of fire injuries occurred in 1995 (three injuries caused by three fires). The sources that caused most of the fire injuries were flame cutting/welding spark/slag/flames, heat sources and pressurized can explosions, and hydraulic fluid/fuel sprayed onto equipment hot surfaces. Other ignition sources were an electrical short/arcing/battery explosion and a source used to light a training fire. The equipment most often involved included oxyfuel torches, heaters, mobile equipment, batteries, and turnout gear. The locations where most of the fire injuries occurred were flame cutting/welding, maintenance, and mobile equipment working areas. Other fire locations were charging stations and fire training areas.

The fire fatality in West Virginia in 1991 may actually have been caused by cardiac failure, although the victim's body was found among the burnt office rubble [MSHA 1991c].

SURFACE COAL MINE FIRES

Table 19 and figure 7 show the number of fires and fire injuries for surface coal mines by state during 1990–1999. Table 19 also shows by state the risk rates, employees' working hours, lost workdays, and coal production.

For surface coal mines, 215 fires occurred in 21 states during 1990–1999. Ninety-four of those fires caused 93 injuries and 1 fatality (the yearly average was 21.5 fires and 9.3 fire injuries). Fourteen fires and seven injuries involved contractors. The Ewhr value was 729×10^6 hr (Irr = 0.026), the CP value was $6{,}355 \times 10^6$ st (Frr = 0.034), and the LWD value was 8,141.

Kentucky had the most fires and fire injuries (45 fires and 23 injuries), followed by Pennsylvania (33 fires and 14 injuries), West Virginia (25 fires and 14 injuries), and Indiana (20 fires and 8 injuries). Among these states, Pennsylvania had the highest fire risk rate value (Frr = 0.145), while Kentucky had the highest injury risk rate value (Irr = 0.041).